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A COMPARATIVE STUDY OF HUMAN RESPONSE, INDOORS, TO BLAST NOISE AND SONIC BOOMS

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ABSTRACT

For the past two decades, blast sounds and sonic booms have been assessed in a like manner in the United States using a C-weighted day-night level. Recently, a new method which replaces the C-weighted day-night level has been recommended (Schomer, Nov. 1994), and reviewed and recommended (NRC, 1996). In this new method, as in the old, blast sounds and boom sounds are once again assessed in a like manner. However, while available evidence suggested that in an indoor setting, blast sounds and sonic booms could be treated similarly, evidence in the form of a side-by-side comparison was lacking. The purpose of the study reported herein was to provide the lacking side-by-side comparison data. The study tested if subjects indoors responded in a like manner to both blast and boom sounds. This study also tested if the response of subjects to sonic booms followed the new method suggested in Schomer (Nov. 1994). A key factor in the design of this study was the presentation of real blasts and booms to subjects situated in real structures in the field. The study was performed as a paired-comparison test with the same control sound being used for both the blast and the boom sounds. About 225 subjects each judged 20 booms and 30 blast sounds. Overall, there were 270 blasts and 180 sonic booms created for this test. The results show good general agreement with the new method. However, there is an indication that for the same C-weighted sound exposure level, a boom is slightly more annoying than a blast. It is the low frequencies which induce vibrations and rattles in buildings. Since the booms have far more low-frequency energy than the blasts, this may imply that a frequency-weighting with a lower cutoff frequency than the 20 Hz of C-weighting should be used for high-energy impulse noise assessment.

A Comparative Study of Human Response, Indoors, to Blast Noise and Sonic Booms

1. INTRODUCTION

Predicting human response to high-energy impulsive sounds such as the sounds generated by sonic booms or explosives is a difficult problem. Much research has been undertaken on sonic booms in the United States (von Gierke & Nixon, 1972; Leatherwood & Sullivan 1993) and Europe (Broadbent & Robinson, 1964; Webb & Warren, 1965) in connection with the US Supersonic Transport, the British/French Concorde, and the US High-Speed Civil Transport. Recently, there has been a fair amount of research on blast sounds, notably in the USA (Schomer; 1991, Mar. 1994, 1995), Germany (Buchta, 1989), and Australia (Cook, 1994). In the United States, blast sounds and sonic booms have been assessed in an identical manner for the past 20 years. Until mid-1996, these two sources of sound were assessed using the C-weighted day-night sound level (ANSI, 1986).

Schomer (1994) proposed a new method for the assessment of high-energy impulsive sound based primarily on blast noise research. This new method was based on a large body of research results which shows that (1) a 1 dB increase in CSEL of a blast sound corresponds to about a 2 dB increase in the A-weighted sound exposure level (ASEL) of an equivalently annoying control sound; and (2) groups of test subjects are equally annoyed by a blast sound at a CSEL of 103 dB, a vehicle passby at an ASEL of 103 dB, or band-limited (200 to 1500 Hz) white noise at an SEL of about 104 dB. The National Research Council (NRC) has recently reported on the assessment of high-energy impulsive sound, and it has included the method proposed by Schomer (Nov. 1994) as one of two recommended methods (NRC, 1996). The Schomer method is recommended when the distribution of C-weighted sound exposure levels for the blast or boom events is known and the standard deviation of the levels is large.

In ANSI (1986) and NRC (1996), blast sounds and sonic booms are treated in a like manner. While these two sources are grouped together for assessment purposes, evidence for this grouping in the form of a side-by-side comparison has been lacking. Prior to this present study, there had never been a single experiment of significant size that used these two sources together.

The purpose of the study reported herein was to test (1) if subjects indoors responded in a like manner to both blast and boom sounds and (2) if the response of subjects to sonic booms followed the function proposed by Schomer for relating event sound CSEL to control ASEL. A key factor in the design of this study was the presentation of real blasts and booms to subjects situated indoors in real structures in the field. Like earlier blast noise research (Schomer; 1991, Mar. 1994, 1995), this study was performed as a paired-comparison test. The control sound used in the previous blast sound research was used herein for both the blast and the boom sounds alike. (A shorter preliminary version of this paper was presented in INTERNOISE 96).

2. STUDY APPROACH

This study tested human response to sonic booms and blast sounds as observed indoors in one unified experiment. The study was performed during August 1995 at the Naval Air Station (NAS) Fallon, NV. The study site was located in the Nevada desert almost centrally within a 15,000 sq. km. supersonic flying area. Three differing test structures were located at the test site. One structure was a rehabilitated heavy brick house with a large flat timber beam, wooden roof covered with about 35 cm of small gravel stones. The main room in this house was about a 5.5 m by 7 m living room. The second structure was a rather small, single-room, 3 m by 6 m wood frame building. The third structure was a large mobile office trailer which was divided into two 3.5 m by 8 m living rooms. Each test room was furnished like a normal living room including couches and chairs, carpets or rugs, coffee and end tables, window treatments, etc. The booms and blasts came from about the same direction and each room had windows which faced the blast site and the direction of arrival of the sonic booms. All windows in each test room were closed. Each room was cooled using a quiet evaporative air conditioner ducted through muffler sections. The ambient A-weighted sound level in unoccupied rooms was about 40 dB. Two walls of the brick house received the blasts and booms (each at an incidence angle of about 45 degrees), the smaller wall of the wood house directly (face-on) received the blasts and booms, and the long wall of the mobile office structure directly received the blasts and booms. Figure 1 shows the test site layout including the study site where the structures and subjects were located, the blast site, and the general aircraft supersonic flight tracks, and Fig. 2 is a photograph of the test site structures and acoustical measurement van.

The study duration was two weeks. During this time, 9 separate groups of subjects participated in the study. Each group consisted of about 25 subjects who judged about 20 boom and 30 blast sounds. Overall there were a total of about 225 subjects, 180 boom sounds and 270 blast sounds.

Sonic booms were produced by Navy F-5 fighter aircraft flying at about Mach 1.2,

typically at 21,000 to 32,000 ft. above ground level. The aircraft established the specified mach/altitude conditions 20 km from the test site and maintained these conditions to within about 7 km of the test site. The central flight track was aimed directly at the study site. Other flight tracks laterally offset from the central flight track were used to generate lower sonic boom levels; the larger the offset, the smaller the boom level. Offsets up to 10 km were utilized.

The blasts were produced by C-4 explosives set off on posts at a height of about 0.9 m. The blast site was located about 900 m from the test houses and, to achieve various blast levels and signatures, 3 sizes of blast charges were used: (1) the big blast which was 2.26 kg of C-4 explosives, (2) the small blast which was 1/4 the size of the large blast or 0.55 kg, and (3) the double blast which was two 1.13 kg charges. These double blasts were set off simultaneously but were separated by about 30 m to achieve a 100 ms delay at the test houses. This double blast was created to have a blast sound which somewhat mimicked a sonic boom.

One outdoor microphone was located about 10 cm (the windscreen radius) from the blast/boom-facing wall of each structure. Each of these microphones was located on a flat open part of the wall. In addition, there was one microphone located at a height of 1.2 m in an open field away from any reflecting surfaces. These 4 microphones were Brüel & Kjær (B&K) Type 4921 outdoor microphone systems but were specially modified to have a low-frequency cutoff of about 2 Hz. In addition, there were 2 very low-frequency sealed B&K Type 4145 microphones (nominally 0.1 Hz cutoff). One was situated near the front wall of the trailer and the other was set up as a ground plane microphone.

In general, the outdoor flat-weighted peak sound pressure levels of the booms measured at the face of a building were about 120 to 135 dB. The corresponding boom C-weighted sound exposure levels (CSEL) were about 26 dB below the flat-weighted peak sound pressure levels. A few boom peak sound pressure levels were higher than 135 dB and many were lower than 120 dB. The combination of high surface temperatures, large negative temperature gradients, winds from the test site towards the aircraft (headwinds), and the limited operational capabilities of the

F-5 aircraft resulted in many flights that were very nearly at Mach cutoff where the booms do not reach the ground due to atmospheric refraction. A typical peak, flat-weighted sound pressure level for the big blast was 129 dB and a typical peak level for the small blast was 123 dB. The double blast had a peak level of about 126 dB. For single blasts, the CSEL was about 25 dB below the peak, flat-weighted sound pressure level and for the double blasts, this difference was about 22 dB.

The test was performed using the paired-comparison study methodology. Subjects arranged in each of the three test structures listened to pairs of sounds. One sound in each pair was a blast or boom test sound. The other sound (control sound) in each pair was a 0.5 second long band limited white noise burst presented to the subjects via loudspeakers placed in each living room. The blast or boom test sound was randomly presented first or second in each pair of sounds. The two sounds in each pair were presented within about 30 s of one another. The control sounds and test methodology were very similar to those used in previous blast noise research (Schomer, 1991; Mar. 1994; 1995).

Each day's new group of 25 subjects was brought to the site by bus. There, the test was explained and they received training on the conduct of the test using pairs of white noise signals. There was a supervisor with each group of subjects. Control lights operated from the instrumentation van signaled when the subjects should listen to each sound in a pair and when they should mark their answer sheet. The answer sheet itself was similar to previous tests and was a machine-readable form which the subjects marked. Subjects were required to select the "more annoying" sound from each pair of sounds. In addition, the subjects reported how difficult it was to make their decision on a 5 point numerical scale anchored by the adjectives *very easy* and *very hard.*

Microphones located near the subjects at ear level recorded the indoor test and control signal levels. The primary metrics used were the test sound CSEL and the control sound A-weighted sound exposure level (ASEL). The control sound was adjusted such that at low sound

levels, nearly all of the subjects would find the test sound more annoying and at high control sound levels, nearly all of the subjects would find the control sound more annoying. In between was the point where 50 percent of the subjects found the test sound to be more annoying and 50 percent found the control sound to be more annoying. This was the equivalency point, the point where the annoyance generated by the test sound (blast or boom) was equivalent to the annoyance generated by the control sound.

To perform the analysis, the blast and boom signals were divided into 4 dB wide bins. The bin center was used to designate the blast or boom level. The data in any bin contained many control levels so it was possible to plot the percent finding the test signal more annoying as a function of the control signal level. For each such bin, event type and room, the data were plotted and a transition function was fit to the data using a commercial, PC, curve fitting software package. This package also plotted the 95 % confidence limits to the transition function. The 50 percent equivalency point was found for each such curve.

Figure 3 shows a typical transition curve. This particular transition curve shows the percentage of respondents from the brick house that found a boom sound more annoying than a control sound as a function of the control sound ASEL. The boom sound data used in this figure are outdoor data and are for the bin with CSELs between 108 and 112 dB. The bin center is 110 dB. The equivalency point is read (with a cursor on the computer screen) directly from the graph and has a control sound level of 88.1 dB.

Each pair of points in Table 1 or 2 comes for a transition curve figure like Fig. 3. For example, the value listed for the "Brick House Boom" in the "110 dB" column of Table 2 is 88.1 dB; the value which comes from Fig. 3. Bins not represented in Table 1 or 2 did not have sufficient data to create a good transition curve. Each bin was 4 dB wide. The bin centers were chosen to maximize the number of good data bins and are indicated in the table headings. Overall, each table summarizes the results from about 225 subjects, each of whom responded to 20 boom and 30 blast sounds.

3. ANALYSIS AND DISCUSSION

General blast/boom analysis

Analysis was performed by plotting the pairs of equivalency points developed from each data bin. The starting point for the analysis was the earlier overall blast noise results from Munster and Grafenwöhr Training Area (GTA), Germany and Aberdeen Proving Ground (APG), MD, USA (Schomer, Nov. 1994). Figure 4 reproduces these earlier blast noise results and includes a regression line which has been fit to these data. This figure compares the indoor measured blast sound CSELs with equivalently annoying white-noise control sound ASELs. The most recent data from the NAS Fallon tests (contained in Table 1) also are plotted in Fig. 4. Examination of Fig. 4 shows that the recent, measured indoor results from the Fallon tests are generally similar to the earlier blast noise data but there is quite a bit of scatter to the data.

Interestingly, the subjects responded to the double 2.25 kg blast sound in exactly the same manner as they did to the single blast sounds of comparable energy. For this reason, we grouped all of the blast sound data together in the following analysis.

These recent Fallon test data, like the earlier blast noise results, are indoor-measured C-weighted sound exposure levels (CSEL). But it is not clear that CSEL should be measured indoors near to the subjects. All environmental noise is normally measured or predicted outdoors. Further, in the case of high-energy impulsive sounds, the C-weighting was not chosen for its ability to correlate directly with human response. Rather, the C-weighting was chosen primarily to provide a standardized measure which incorporated the low-frequency sound pressures associated with high-energy impulsive sounds, since these low-frequency energies most contribute to building vibrations and rattles (CHABA, 1996). This is best represented by the outdoor measured CSEL, not the CSEL measured near the subjects ears. Therefore, it is appropriate to examine these same relations using outdoor-measured CSEL. To do this, the earlier blast data from Fig. 4 were converted to portray the results with outdoor-measured CSEL. These converted data are displayed in Fig. 5.

Outdoor measured CSEL are shown in Fig. 5 as a function of indoor-measured, equivalently annoying white noise control sound ASEL. (The indoor measured control sound levels are used because there were no corresponding outdoor measured levels for sounds created by indoor-located loudspeakers.) For the recently acquired results from the Fallon tests, all of the subject data were reanalyzed using actual outdoor CSEL measurements. These data also were combined into bins. Table 2 contains the results of this analysis. For the earlier blast noise data (Schomer, Nov. 1994), the outdoor-measured CSEL were approximated as the indoor-measured CSEL plus a constant. For APG, the original outdoor and indoor measured data were used to find a constant difference of 14 dB. This difference had a standard deviation of less than 1 dB. For Munster, the original data were used to find a constant difference of 12 dB, again with a standard deviation of less than 1 dB, and for the earlier GTA data (where the original data are no longer readily available), an average value of 13 dB was used.

Like Fig. 4, Fig. 5 includes the earlier blast data and a regression line which has been fit to these data. Figure 5 also includes the outdoor-measured NAS Fallon data from Table 2. One can compare the fit of the Fallon data to the respective regression lines in Figs. 4 and 5. The variance of the Fallon data based on indoor-measured CSEL's (Table 1) from the regression line in Fig. 4 is 10.4 dB; the variance of the Fallon data based on outdoor-measured CSEL's (Table 2) from the regression line in Fig 5 is 3.2 dB. The fit is clearly better in Fig. 5. This result tends to reinforce the concept that C-weighting is a useful **outdoor** measure for assessing the indoor community response to high-energy impulsive sounds. It should only be used outdoors—not indoors. Since one reason for choosing C-weighting was to include those acoustical energies which induce building vibrations and rattles, it is inferred that the outdoor measured CSEL works better than the indoor measurements because it is the outdoor measurements which correlate with induced building vibrations and rattles. The indoor C-weighted measurements predict neither building response nor human response.

Comparison of blast and boom results

Figure 5 shows that for the same CSEL, in the brick house and mobile office trailer, the annoyance created by sonic boom sounds was greater than the annoyance created by blast sounds.. The boom level should be about 5 dB below the blast level for equal annoyance. In the wooden house, the annoyance responses to both blasts and booms were equal for equal CSEL.

In general the NAS Fallon data fit the existing wider body of blast data fairly well. The blast data from Fallon typically lie about 3 dB above (less annoying) the regression line fit to the earlier blast sound data (Schomer, Nov. 94), but well within the range of previous blast data. The sonic boom data typically lie about 1 dB below (more annoying) this regression line. The fit of the sonic boom data to the blast sounds regression line is really excellent.

The discrepancy between the blast and boom occurs primarily for the brick house and the trailer. The boom and blast data points for the wooden house align with one another. The brick house and trailer data may indicate that C-weighting is not the ideal measure for high-energy impulsive sounds. The booms had much more low-frequency energy than did the blasts. Therefore, a weighting that would cut off at a frequency lower than 20 Hz (including more of the energies which cause a building to vibrate) would allow greater correlation of these data sets.

Table 3 contains the results of filter analysis on a small set of typical blast and boom data recorded at NAS Fallon. These particular data were recorded using the outdoor ground-plane microphone having a 0.1 Hz low-frequency cutoff and an instrument-grade DAT recorder set for DC operation. The data in the table compare 3 sets of outdoor-measured blast and boom signatures. The three sets were chosen such that their outdoor-measured CSEL were about equal. Each was analyzed using a Krohn-Hite Model 3343 Filter used in its high-pass filter mode. These recordings were analyzed repeatedly with progressively lower high-pass filter cutoff settings. First the cutoff was set to 20 Hz, and then progressively to 10, 8 and 5 Hz. Table 3 also contains the original field-measured CSEL and the CSEL measured in the laboratory from the recordings. These data show that the recordings accurately reflect the field data. The

differences between the CSEL and the Krohn-Hite filter set to 20 Hz reflect the fact the Krohn-Hite filter has an 8th order Butterworth characteristic which is substantially different from C-weighting. Also, the C-weighting filter is down 6 dB at 20 Hz.

Table 4 contains just the averages of the Krohn-Hite filtered data from Table 3. It shows the progressive differences of the lower-frequency settings from the 20 Hz setting. Finally, it shows the difference of these differences between boom and blast sounds. The difference of the differences offers an indication as to what might have occurred if a filter with a lower frequency cutoff than the 20 Hz of C-weighting had been used for the analysis. When the Krohn-Hite filter cutoff is set to 5 Hz, then the difference of the differences is 4.6 dB. This change of 4.6 dB would have been sufficient to make the brick house and office trailer blast and boom data from NAS Fallon align together. Of course, the wooden house data would align less well by 4.6 dB. Overall, if the analysis in this study had been done with a filter having a 5 Hz cutoff rather than a 20 Hz cutoff, then the preponderance of the boom and blast data would have aligned with one another. Thus, this discussion indicates that a weighting more inclusive of low frequencies than C-weighting might be even better for assessing high-energy impulsive sounds. The indication is that a cutoff of about 5 Hz might be best.

4. CONCLUSIONS

A field study has been conducted to test if subjects responded in like manner to both blast and sonic boom sounds and to test if the response of the subjects to sonic booms followed the method suggested in Schomer (Nov. 1994). A key factor in the design of this study was the presentation of many real blast and boom sounds to subjects situated indoors in real structures in the field

The results of these present studies show that only the outdoor-measured CSEL should be used to predict human and community response to high-energy impulsive sounds. The variance between the measured CSEL data and a regression line fit to earlier blast sound data is far less for outdoor-measured data than for indoor-measured data. Since one reason for choosing C-weighing was to include those acoustical energies which induce building vibrations and rattles, it is inferred that the outdoor measured CSEL works better than the indoor measurements because it is the outdoor measurements which correlate with induced building vibrations and rattles. The indoor C-weighted measurements predict neither building response nor human response.

The general results show that human response to sonic booms and blast sounds is quite similar. There is some indication that response to booms is greater than response to blasts for the same CSEL. However, all of the house and mobile office data fit the wider body of blast data quite well, so regression curves fit to this wider body of data provide a good overall empirical high-energy impulsive noise assessment tool.

The results in this study certainly support the general inclusion of sonic boom sounds into the framework developed primarily for blast sound. The sonic boom data from the present field study at Fallon are quite similar to the Fallon blast data and to the large body of earlier blast sound data.

The difference between blast and boom sound responses offers one indication that a weighting with a lower cutoff than 20 Hz (C-weighting) should be used to assess high-energy impulsive sounds.

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Bin Center CSEL (dB)	90	94	98	102	106
Brick House Blast	70	79.5			
Brick House Boom	83	88.1			
Trailer Blast		74	80.8		
Trailer Boom		84	88.2		
Wooden House Blast			70.8		
Wooden House Boom				77.5	85.3

Table 1. Equivalently annoying white noise control sound ASEL in decibels for the blast or boom CSEL bin center indicated. The CSEL are measured **indoors** and the control sound ASEL are measured indoors. Each pair of points on this table come from a transition curve figure like Fig. 3. Bins not represented on this table did not have sufficient data to create a good transition curve. Each bin was 4 dB wide. Bin centers were chosen to maximize the number of good data bins. Overall, this table summarizes the results from about 225 subjects, each of whom responded to 20 boom and 30 blast sounds.

Bin Center CSEL (dB)	102	106	110	114
Brick House Blast		69.2	79.5	
Brick House Boom	75.1	81.6	88.1	95.3
Trailer Blast		74.8	81.9	
Trailer Boom	76.7	84.4	90	
Wooden House Blast			82.4	
Wooden House Boom			83.4	

Table 2. Equivalently annoying white noise control sound ASEL in decibels for the blast or boom CSEL bin center indicated. The CSEL are measured **outdoors** and the control sound ASEL are measured indoors. Each pair of points on this table come from a transition curve figure like Fig. 3. Bins not represented on this table did not have sufficient data to create a good transition curve. Each bin was 4 dB wide. Bin centers were chosen to maximize the number of good data bins. Overall, this table summarizes the results from about 225 subjects, each of whom responded to 20 boom and 30 blast sounds.

	Original Measured CSEL (dB)	CSEL Analyzed from Tape (dB)	Krohn-Hite 20 Hz SEL (dB)	Krohn-Hite 10 Hz SEL (dB)	Krohn-Hite 8 Hz SEL (dB)	Krohn-Hite 5 Hz SEL (dB)
Blast 1	94.5	94.3	97.2	99.6	99.8	100.0
Blast 2	94.3	94.2	97.1	99.2	99.4	99.5
Blast 3	94.2	94.0	97.0	99.5	99.7	99.8
Blast Average	**94.3**	**94.2**	**97.1**	**99.4**	**99.6**	**99.8**
Boom 1	97.3	97.1	99.3	102.4	103.6	105.6
Boom 2	92.6	92.3	93.9	99.1	100.5	102.5
Boom 3	99.6	99.5	100.0	105.0	106.0	106.9
Boom-Average	**96.5**	**96.3**	**97.7**	**102.2**	**103.4**	**105.0**

Table 3. Analysis of selected blasts and booms. This table contains the analysis of 3 blasts and 3 booms recorded at NAS Fallon. The table contains filter analysis using a Krohn-Hite Model 3343 high-pass filter set to the frequency indicated. The table also contains the original field-measured CSEL and the CSEL measured in the laboratory from the recording. These data show that the recordings accurately reflect the field data. The differences between the CSEL and the Krohn-Hite filter set to 20 Hz reflect the fact the Krohn-Hite filter has an 8th order Butterworth characteristic which is substantially different from C-weighting. Also, the C-weighting filter is down 6 dB at 20 Hz.

	Krohn-Hite 20 Hz SEL (dB)	Krohn-Hite 10 Hz SEL (dB)	Krohn-Hite 8 Hz SEL (dB)	Krohn-Hite 5 Hz SEL (dB)
Blast Average	97.1	99.4	99.6	99.8
Blast Difference from 20 Hz	0.0	2.3	2.5	2.7
Boom Average	97.7	102.2	103.4	105.0
Boom Difference from 20 Hz	0.0	4.4	5.6	7.3
Difference of Differences, Boom minus Blast	0.0	2.1	3.1	4.6

Table 4. This table repeats the averages for blast and booms analyzed using the Krohn-Hite high-pass filter set to the frequencies indicated. It also shows the differences for blast and boom data from 20 Hz, and the difference of the differences. The difference of the differences shows that when the filter is changed from the 20 Hz to 5 Hz, the relative analysis SEL for boom sounds rises by 4.6 dB relative to the same SEL analysis for blast sounds.

CAPTIONS

Figure 1. This figure shows the study layout. A photograph of the structures at the study site is given in Figure 2. The blast site is about 900 m from the structures. The supersonic flight tracks are about 13 km long and begin about 7 km from the study site. The central flight track was aimed directly at the study site. Other flight tracks laterally offset from the central flight track were used to generate lower sonic boom levels; the larger the offset, the smaller the boom level. Offsets up to 10 km were utilized. To generate the booms at the study site, the aircraft flew towards the site.

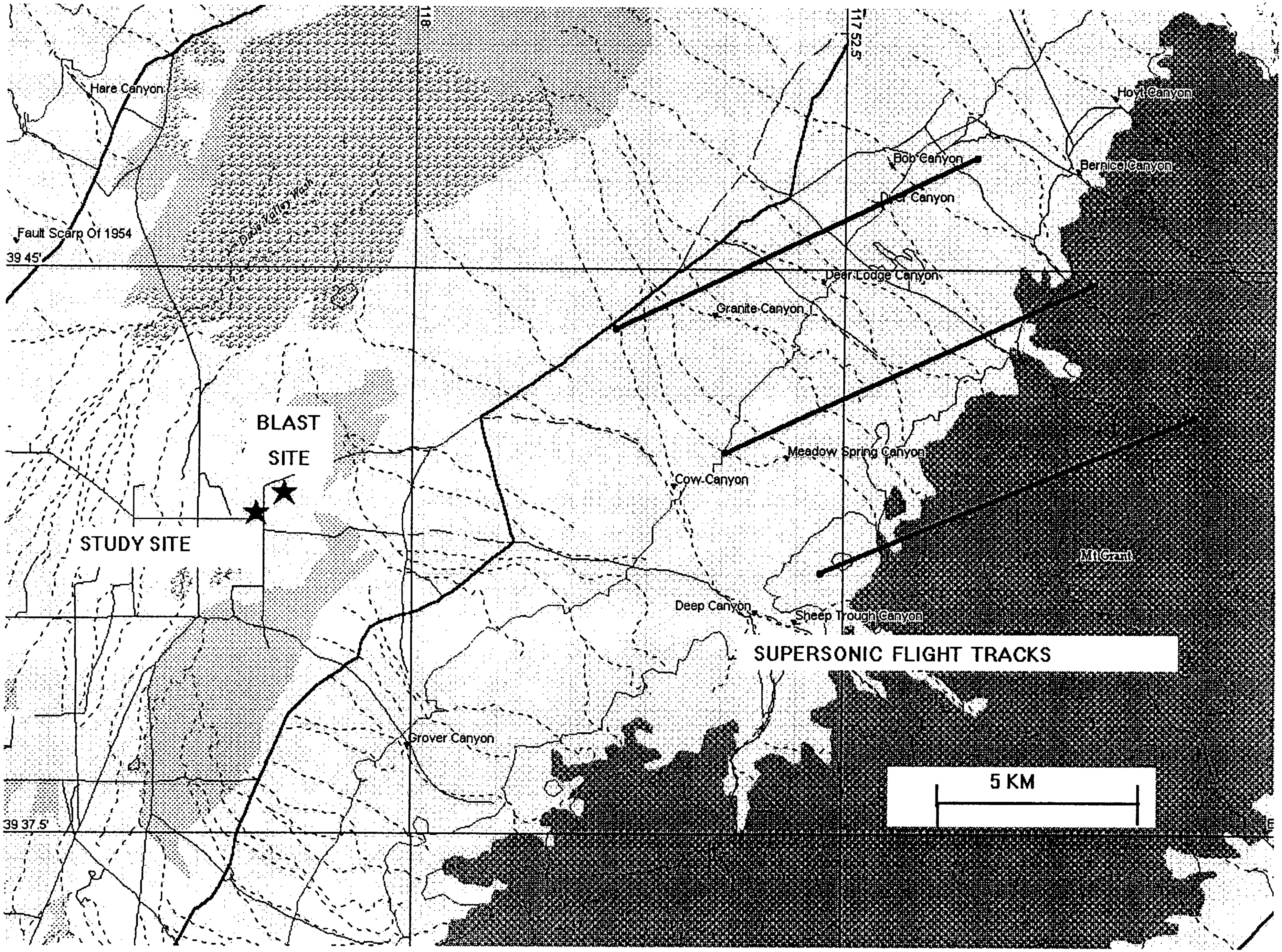
Figure 2. This figure shows the 3 structures and the measurement van at the study site. The structures included the brick house, the small wooden house, and the mobile office trailer which was divided into two rooms.

Figure 3. This figure shows a typical transition curve. One of these curves was produced for each entry in Table 1 or 2. A commercial curve-fitting program was used to fit a transition curve to the data, along with the dashed 95% confidence limits. These transition curves determine the equivalency point; the point where 50 percent of the subjects find the blast or boom more annoying and 50 percent find the control sound more annoying. This is the point where the annoyance generated by the two sounds, the blast or boom sound and the control sound, are equivalent. This figure shows the percentage of respondents from the brick house that found a boom sound more annoying than a control sound as a function of the control sound ASEL. The boom sound data used in this figure are outdoor data and are for the bin with CSELs between 108 and 112 dB. The bin center is 110 dB. The equivalence point is read (with a cursor on the computer screen) directly from the graph and has a control sound level of 88.1 dB. This is the value listed for the "Brick House Boom," 110 dB column in Table 2

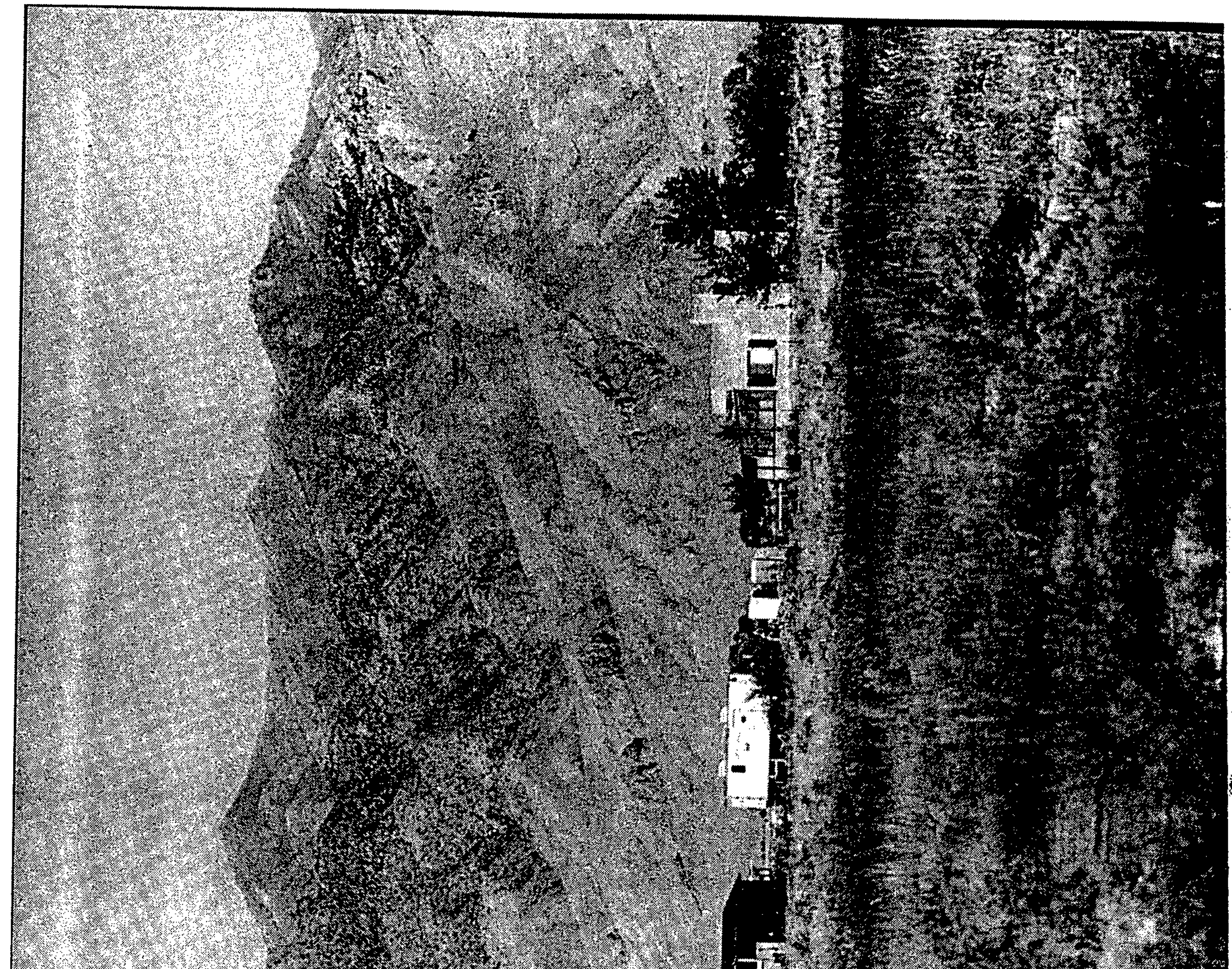
Figure 4. C-weighted sound exposure level of blast or boom sounds versus A-weighted sound exposure level of equivalently annoying control sound. Blast and booms measured **indoors**; control sound measured indoors. The recent NAS Fallon data are shown compared to earlier (indoor) blast data and a regression line fit to those blast data.

Figure 5. C-weighted sound exposure level of blast or boom sounds versus A-weighted sound

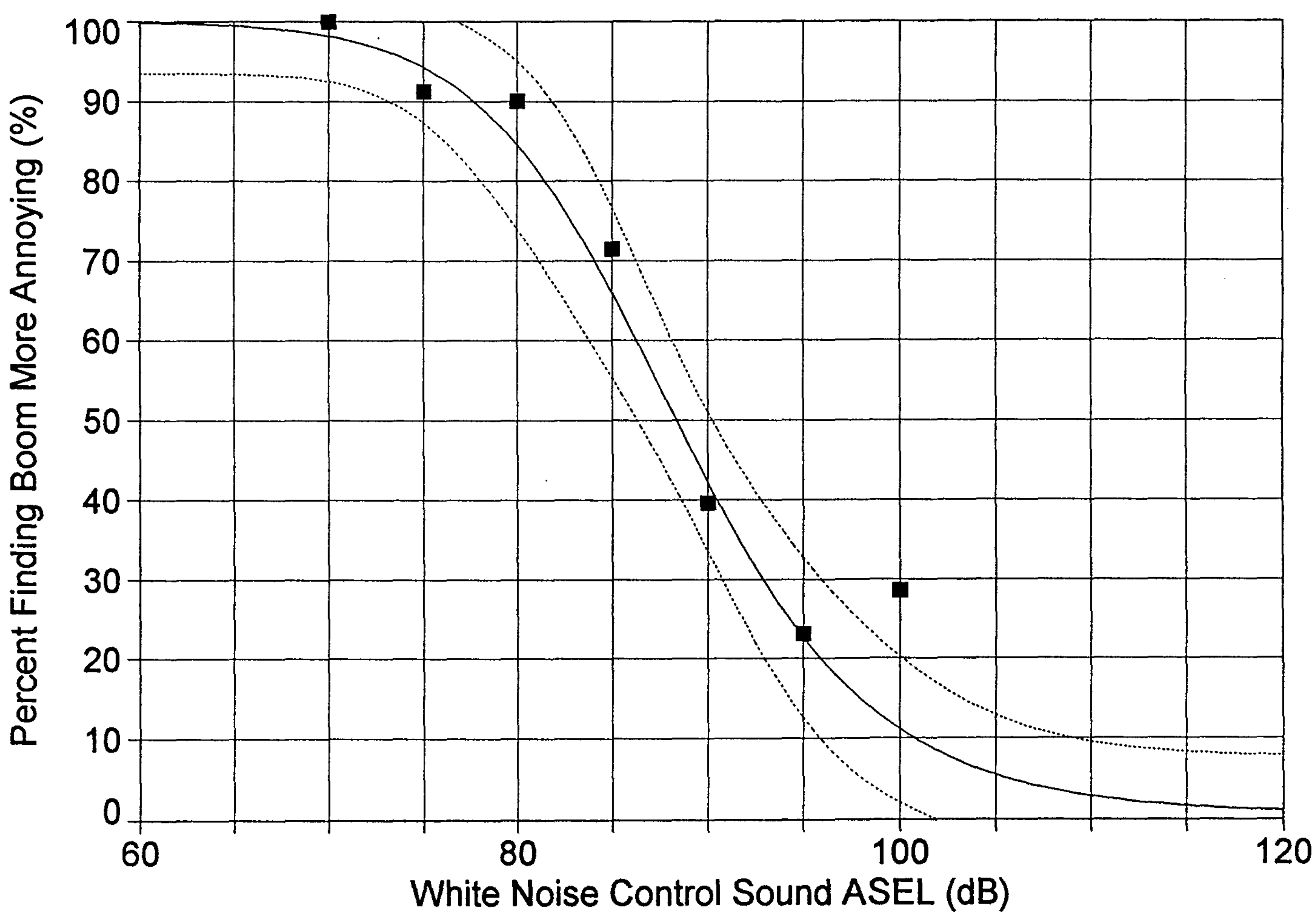
exposure level of equivalently annoying control sound. Blast and booms measured **outdoors**; control sound measured indoors. The recent NAS Fallon data are shown compared to earlier (outdoor) blast data and a regression line fit to those blast data.



118
117 52.5'
Hare Canyon
Fault Scarp Of 1954
39 45'
Bob Canyon
Dry Canyon
Hoyt Canyon
Bernice Canyon
Deer Lodge Canyon
Granite Canyon
BLAST
SITE
STUDY SITE
Meadow Spring Canyon
Cow Canyon
Mt Grant
Deep Canyon
Sheep Trough Canyon
SUPERSONIC FLIGHT TRACKS
Grover Canyon
5 KM
39 37.5'



Schomer & Sias Figure 3



Schomer & Sias Fig. 4 -- indoor data